we have done additional work and submitted it to Psychology and Aging.

NAVAL SUBMARINE MEDICAL RESEARCH LABORATORY

SUBMARINE BASE, GROTON, CONN.

REPORT NUMBER 1039

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Naval Medical Research and Development Command
Research Work Unit M0100.001.1023

Released by:

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Commanding Officer
Naval Submarine Medical Research Laboratory

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SUMMARY PAGE

PROBLEM

To determine if light leaks around the edges of an eye patch on spectacle frames affect dark adaptation when worn in ambient light levels found aboard submarines.

FINDINGS

There was virtually no effect on dark adaptation of patching the eye when worn in an ambient light level of 0.4 fL. Under the "maintenance" light level of 15 fL, the times taken to recover full dark adaptation with the patched eye gradually increased with increasing exposure durations; but after 5 minutes under that light level, the mean time required to recover was less than one minute. There was a significant difference in the performance of subjects under 40 years of age and those over 40; those over 40 were much more affected by the light leaks.

APPLICATION

These results indicate that a periscope operator will not degrade his level of dark adaptation by using a patch attached to spectacle frames when worn under low levels of ambient illumination.

ADMINISTRATIVE INFORMATION

This research was conducted under Naval Medical Research and Development Command Work Unit M0100.001-1023--"Enhanced visual performance on submarines." It was submitted for review on 19 Oct 1984, approved for publication on 16 Nov 1984, and designated as NAVSUBMEDRSCHLAB Rep. No. 1039.

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ABSTRACT

The effects on dark adaptation of light leaking around the edges of a spectacle frame worn under ambient light levels of 0.4 and 15 foot-Lamberts for 0.5 to 5 minutes were measured. Younger observers were virtually unaffected by light leaks in ambient illumination of 0.4 fL. However, after 5 minutes in ambient illumination of 15 fL, they required about 45 seconds to recover complete dark adaptation, and observers over the age of 40 required nearly three minutes.

INTRODUCTION

Night vision sensitivity is extremely important to periscope operators, and the attainment and preservation of dark adaptation is accordingly of great concern to them. A large body of experimental work has clearly established that dark adaptation is faster after exposure to red than to white light [1]. Moreover, it is well known that when an observer is adapted to a high intensity of light, it takes about half an hour to reach a state of more or less complete dark adaptation [2]. Consequently, it has long been standard procedure aboard submarines to turn on red lights or put on red goggles half an hour before night vision will be required. The periscope operator would prefer all ambient light to be extinguished-- and this is often done-- but it is not always feasible to do so in the control room, because the other crewmen require some light to carry out their duties.

The official use of the red goggles and the general dark adaptation procedure have given rise to a number of misconceptions. One is that red adaptation is equivalent to dark adaptation. This is not true. The level of adaptation permitted by red goggles or red illumination is far short of complete adaptation and is generally achieved in about 5 minutes. The practice of wearing red goggles for half an hour is not necessary for, no matter how long an individual is exposed to red light, he will never become completely dark adapted [3-5].

It was for this reason that the proposal was made that periscope operators should wear a black patch over one eye rather than red goggles. The two eyes are photochemically independent, and one eye can be dark adapted while the other is light adapted [6,7]. Thus the control room could be illuminated and the crewmen and the periscope operator (with one eye) could see inside the compartment; at the same time, the operator would be ready to look through the periscope with his other eye which has been patched.

This proposal was not widely adopted. One reason was a second misconception about the dark adaptation process. Many believe that dark adaptation will be destroyed by any exposure to light, regardless of its intensity or duration. Thus some operators were afraid that their dark adaptation would be lost if their eye was accidentally exposed to the ambient light when they removed the patch to look through the periscope or if they forgot to close their eye when they looked away from the periscope until the patch was in place. In fact, light adaptation, like dark adaptation, is not instantaneous [2]. The effect of light on dark adaptation depends on its intensity and duration [8,9]. Under the

conditions found in the control room, it is unlikely that the effects of brief accidental exposure to the light would be long lasting.

A second objection to the patch was that it was uncomfortable. Many individuals found it annoying to have their eyelashes rubbing against the patch. This problem could be alleviated by using spectacle frames with one of the lens holders blacked out, but there are in this case, of course, light leaks around the edges of the patch; once again it was believed that dark adapation would be severely compromised by these leaks.

Although there has been a considerable amount of research on the effects of glare on night vision, the glare sources have typically not been excessively peripheral and have always been distinctly visible [10]. The light leaks around the edges of spectacle frames are extremely peripheral, and under the conditions in which they would be used on a submarine, rather unobtrusive. In fact, the observer has to turn his eyes as much as possible in order to see the light around the edges. The question is, therefore, would these light leaks have an important effect on the state of dark adaptation, particularly under the lighting conditions aboard submarines?

This study measured the changes in dark adaptation produced by the light leaks around an eyeglass frame when it was worn in a room illuminated to two light levels, the dim intensity of 0.4 fL to which the control room is typically illuminated at night, and the "maintenance" light level of 15 fL, the highest intensity found aboard submarines. The effects of four exposure durations on dark adaptation (0.5 to 5 minutes) were measured for each light level. In addition, the effect of age was investigated.

METHOD

Subjects

The subjects were staff members of the laboratory and their dependents who volunteered to participate. Two groups were tested, young observers ranging in age from 19 to 31 (Mean =24) and older observers from 41 to 61 (Mean = 53).

Apparatus

Scotopic sensitivity was measured with a circular test stimulus which, at the viewing distance of 50 cm, subtended 0.57 deg visual angle and was presented 10 deg to the left of a pin point of light which served as a fixation

point. The light for the test stimulus was produced by a slide projector, attenuated by neutral density filters, flickering at about 2 flashes per second, and projected through a baffle box onto a ground glass screen. The stimulus was flickered simply to help the subject decide whether or not he actually saw it. The projection equipment was in one room, and the subject sat in an adjoining light-tight room, facing holes in the wall through which the test stimulus and fixation point were to be seen.

To light adapt the subjects, overhead cool white fluorescent lights were turned on. Two intensities of ambient illumination were tested, 15 fL and 0.4 fL, as measured off a high reflectance white cardboard mounted on the walls on either side of the subject. The level of illumination was controlled by neutral density sleeves around the fluorescent tubes. Four durations of light exposure, 0.5, 1, 2, and 5 minutes, were presented to the subjects in counterbalanced order.

During the light exposure, the subject wore a spectacle frame with the left lens holder open and an opaque black velvet patch over the right lens holder. The left eye was thus exposed to the light, while the right eye was exposed only to the light leaks around the edges of the frame (Fig. 1).

Procedure

After explaining the purpose and procedure of the experiment, the subject was dark adapted. Initially a few subjects were "tracked" with the test stimulus as they dark adapted until they reached a plateau, but most subjects simply sat in total darkness for 25 minutes. Next the dark adapted threshold was measured using the staircase method; The intensity of the test stimulus was decreased in 0.2 log unit steps until the subject could no longer see it; it was then increased in 0.2 log unit steps until he reported it. This was repeated until the lowest intensity at which the subject could reliably detect the stimulus was determined. This was taken as his threshold. The subject then put on the spectacle frames and was exposed to the predetermined intensity and duration of light. At the end of this time, the light was turned off, a stopwatch was started, and the test stimulus was presented at 0.2 or 0.4 log units above threshold. The subject, as soon as the light was turned off, took off the frames, acquired the fixation light, and reported as soon as he could see the test stimulus. Each time the stimulus was detected, it was dimmed by 0.2 log unit until the subject had again reached his threshold. The time

(in seconds) taken to see each intensity was recorded. The subject was then exposed to the next duration of light exposure and the procedure repeated. During a given session, all four durations were tested at the same level of ambient light. A session lasted about 45 minutes.

RESULTS

It became apparent very quickly after testing only a few subjects that the performance of the older subjects was quite different from that of the younger ones. Only the older individuals appeared to be affected by the light leaks. Since few periscope operators much over the age of 40 have served on submarines, subjects under that age were sought to answer the basic question.

Effect of light leaks during night time illumination

The effect of the night-time intensity of ambient illumination (about 0.5 fL) is of most concern. This is the intensity to which the periscope operator would be exposed if any ambient illumination is used. Figure 2 shows the mean times taken to recover complete dark adaptation after exposure to the various durations of the 0.4 fL ambient light by the 12 subjects (ages 19-31). The recovery time was about nine seconds after half a minute of exposure to the ambient light, and it increased gradually to about 17 seconds after five minutes of exposure. These times were not, however, significantly different, according to an analysis of variance.

Effect of age

Since there was apparently an effect of age, 12 subjects, half over the age of 40 (41-61) and half under that age (20-31) were tested in an ambient light level of 15 fL, corresponding to the maintenance level of illumination -- the highest intensity on a submarine.

Figure 2 shows that the recovery times are much longer under the brighter light level for the younger subjects ($F(1,16)= 21.6$, $p <.01$), according to an analysis of variance) and still longer for the older subjects. After half a minute of exposure, the younger subjects recovered complete dark adaptation in about 32 seconds, whereas the older ones required 76 seconds, more than twice as long. After five minutes of exposure, the young group recovered in 49 seconds, whereas the older group required 170 seconds. The increase in recovery time with longer exposure to the ambient light was not significant for the young subjects, but it was very significant for the older subjects ($F (3,15) =$

8.02, $p < .01$), according to an analysis of variance. And the differences in recovery time were significantly longer for the older subjects ($F(1,10) = 7.45$, $p < .05$), according to a 2-way analysis of variance.

Effect of order of presentation

The mean recovery times as a function of order of presentation, averaged across subjects and exposure duration, were calculated to see if the subjects tended to improve their performance with each presentation. Figure 3 shows that there was a tendency for recovery time to decrease with each presentation. This suggests, of course, that the mean recovery times are somewhat inflated as a result of the uncertainty of the subjects during the initial trials.

DISCUSSION

Despite the light leaks around the edges of the frame, the opaque patch in the lens holder clearly provides a considerable amount of protection for the dark-adapted eye. The younger observers recovered their complete dark adaptation in less than 15 seconds after 5 minutes of exposure to the night-time light level found aboard submarines. It must be noted that within this time the subjects had to remove the patch, acquire the fixation point, and decide whether or not they were in fact seeing a test stimulus very close to their absolute threshold. Moreover, most of the subjects were inexperienced in such experiments, and after the first light exposure (one-fourth of the counterbalanced exposures for each duration) the time taken to see the stimulus typically was longer than the subsequent response times. It must further be kept in mind that when one eye is dark adapted while the other is light adapted, it appears to the observer that he is trying to see the test stimulus through a veiling glare. Although the present results have confirmed the original observations [7] that this does not raise the scotopic threshold with experienced observers, it does present a difficulty to some inexperienced observers. Taking all these things into consideration leads us to conclude that dark adaptation was virtually unaffected under the dim ambient light.

Even after 5 min under the "maintenance" level of illumination, which approaches that of a typical office, the younger observers recovered their dark adaptation in less than one minute.

There was, however, an interesting dichotomy between the younger (less than 32 years of age) and the older (more than 40 years) observers. After five minutes under the

ambient light, the older observers required an average of a little more than three minutes to recover their dark adaptation. It has long been argued that older individuals suffer more from problems of glare [11]. Glare generally refers to a light source which is much brighter than the mean brightness level of the field of view--that is, the brightness level to which the eye is adapted. The importance of glare has been demonstrated by measuring the effect of a small glare source on the difference threshold; the difference threshold has been shown to be a function of the intensity of the glare source and its proximity to the test stimulus [12]. The mechanism appears to be stray light [13]. It seems reasonable to assume, therefore, that older people suffer a greater disturbance of dark adaptation from these light leaks because of an increase in the amount of stray light in their eyes. It is well known that there is a large variety of foreign substances suspended in the vitreous, and when they are numerous "there may be diffraction of light with marked reduction in vision "[14,p.280]. This material is believed to represent degenerative changes in the vitreous [15, p.145] which are, thus, likely to increase with age. It seems quite conceivable that in older observers, the peripheral light stimulus is more diffused throughout the eye, stimulates more receptors, and thus raises the level of light adaptation to a greater extent than with younger observers.

The increase in susceptibility to the peripheral light after the age of 40 conforms to the deterioration in absolute visual threshold which has been reported to begin between the ages of 40 and 50 [16].

On submarines, however, there have typically been few crew members much over the age of 40, although the commanders of the new Trident submarines tend to be older than previous submarine commanders. It appears, however, that an ordinary spectacle frame with an opaque patch will suffice to dark adapt most periscope operators who are exposed to night-time illumination levels on the submarine, despite the fact light leaks around the edge. Even most of those leaks can of course be eliminated by opaque shields around the edges of the frames.

A final consideration is the effect of dark adaptation on the momentary exposure to light when the observer is putting his eye to or taking it away from the periscope. These very brief exposures also have very little effect [8,9].

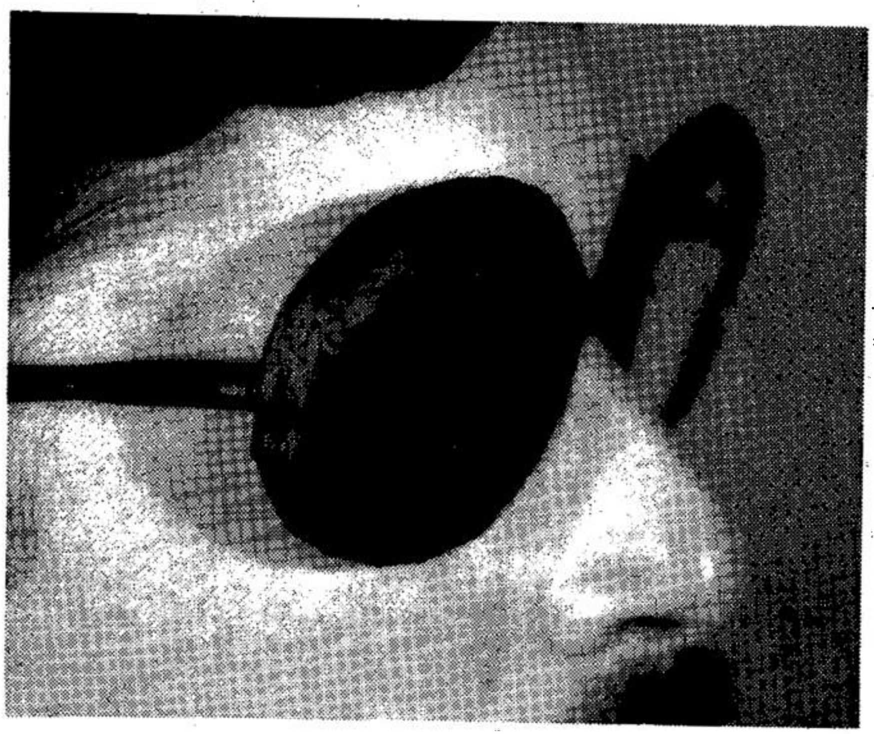

Fig. 1. The spectacle frame used to shield the right eye. The shadow shows the gap between the frame and the face.

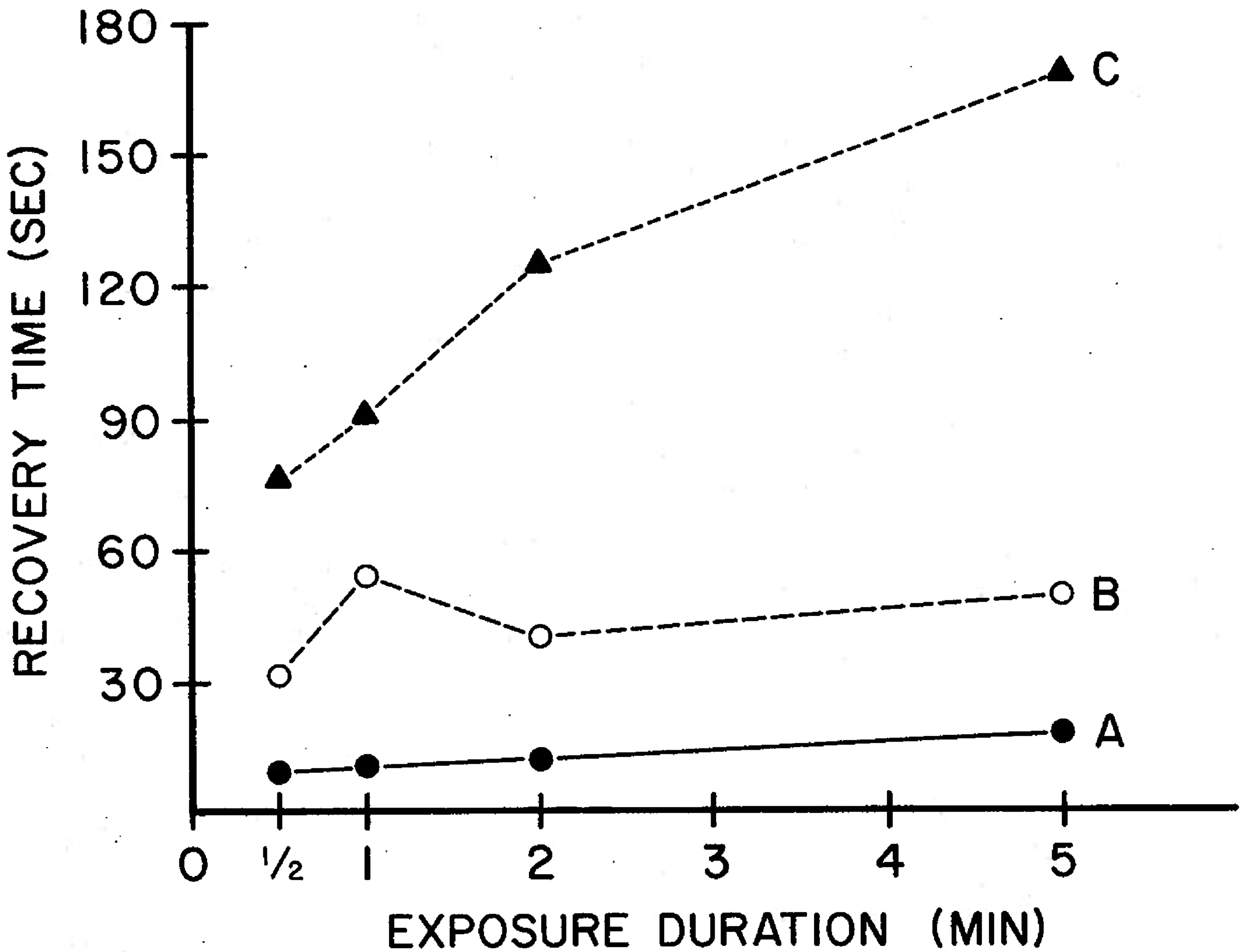

Fig. 2. Mean times required to recover complete dark adaptation after exposure to the various durations of ambient light. (A) 12 young subjects exposed to 0.4 fL. (B) 6 young subjects exposed to 15 fL. (C) 6 old subjects exposed to 15 fL.

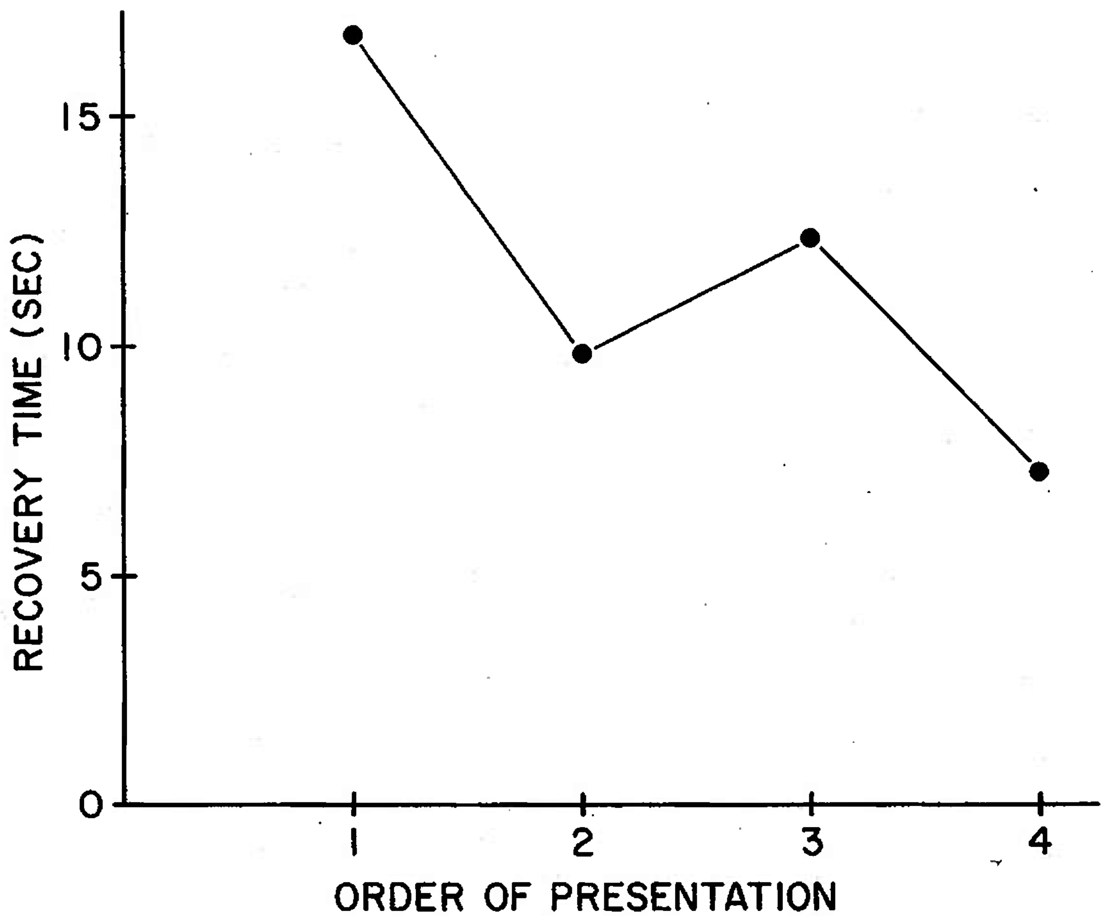

Fig. 3. Mean recovery time as a function of the order of presentation of the various exposure durations averaged across subjects and exposure durations to the dim illumination.

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The effects of dark adaptation of light leaking around the edges of a spectacle frame worn under ambient light levels of 0.4 and 15 foot-Lamberts for 0.5 to 5 minutes were measured. Younger observers were virtually unaffected by light leaks in ambient illumination of 0.4 fL. However, after 5 minutes in ambient illumination of 15 fL, they required about 45 seconds to recover complete dark adaptation, and observers over the age of 40 required nearly three minutes.